S/N 1006599
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2631

Instructions and Applications

Microphone Carrier System Type 2631

A carrier system designed for detection of capacitance variations in the frequency range DC to 150 kHz. Used with a condenser microphone input it provides an ideal first stage processing of low frequency pressure variations such as sonic bangs, thunder storms, short duration pulses etc.

BRÜEL & KJÆR

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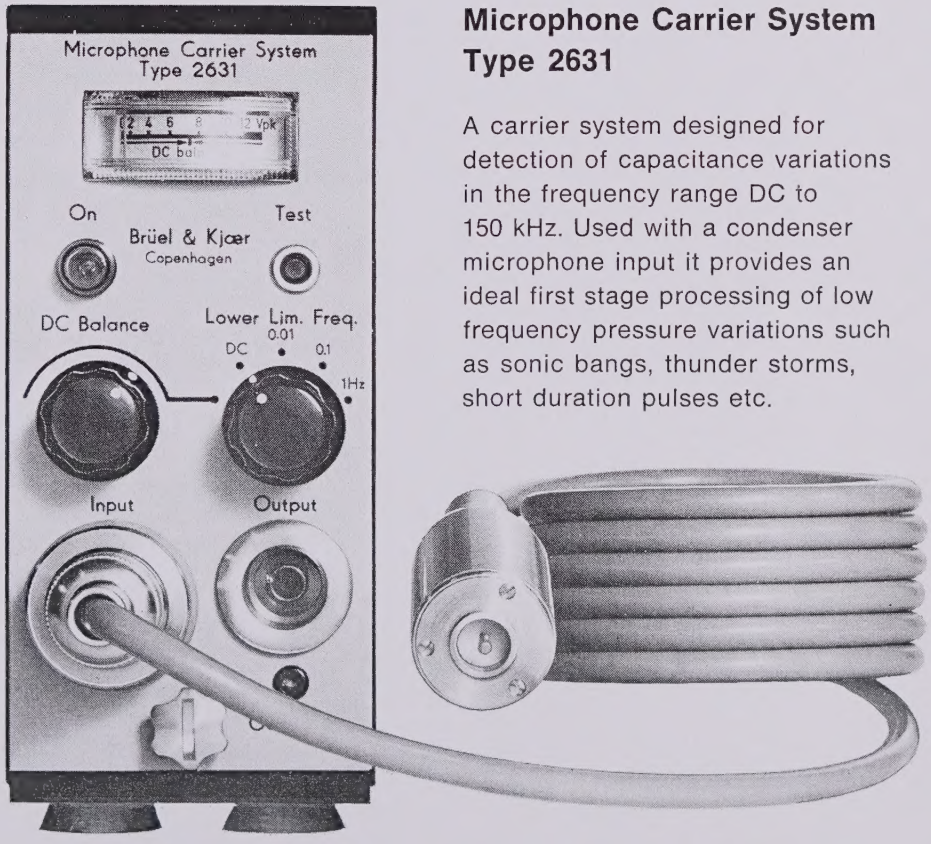

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MICROPHONE CARRIER SYSTEM TYPE 2631

May 1971

CONTENTS

1. INTRODUCTION 5

2. CONTROLS 7

2.1. Microphone and Microphone Head 7
2.2. Control Unit 8
Front Panel 8
Rear Panel 10

3. OPERATION 13

3.1. Connection of 2631 for Calibration and Measurements 13
3.2. DC Balance of Output Signal from the 2631 13
For DC Lower Lim. Freq. Mode 13
For AC Lower Lim. Freq. Modes 14
3.3. Calibration 15
Using the Pistonphone or Sound Level Calibrator 15
Using change in Atmospheric Pressure with Height ... 15
3.4. Evaluation of Output Voltage available from the 2631 18
3.5. Use of Test Oscillator 19
3.6. Battery Operation 20
3.7. Removal of Control Unit's Panels 20

4. DESCRIPTION 22

4.1. Condenser Microphone 22
4.2. Microphone Head 24
4.3. Control Unit 26
4.4. Frequency Characteristics of the 2631 27

5. APPLICATIONS 28

5.1. Sonic Bang Measurements 28
General 28
Measuring Environment 29
Microphone and Installation 30
Extension of Microphone Lower Limiting Frequency 30
Measurement and Analysis 33
5.2. Pressure Measurements 36

6. SPECIFICATIONS 39

6.1. Carrier System with 1 inch Microphone Type 4146 .. 39
6.2. Carrier System with 1/2 inch Microphone Type 4147 Plus Adapter Type UA 0271 39
6.3. Carrier System alone 40

1. INTRODUCTION

The B & K Microphone Carrier System has been designed to meet the exacting requirements called for in the measurement of pressure variations in the frequency range from 0 to 150 kHz. It will be found especially useful in the measurement of slowly varying air pressures and short duration pressure pulses such as those found in sonic bangs, phonetics, wind tunnels, pressure chambers and thunder storms, etc. When used with the B & K Condenser Microphone Type 4147 it complies to the ISO Draft Proposal 43/1 N II for sonic bang measurements.

The Carrier System consists of a Microphone Head and a Control Unit. For measurements a condenser microphone (not provided) is screwed onto the Head. This couples the microphone's output capacitance into the resonant input stage of the Head's FM discriminator. Any change in the microphone's output capacitance due to sound pressure variations at its diaphragm causes the impedance of the resonant circuit to change. The FM discriminator detects the impedance change and produces a demodulated output signal which is directly proportional to the pressure at the diaphragm. Unlike conventional systems, the FM discriminator of the 2631 is contained entirely in the Head and therefore only the demodulated signal is taken from the Head. This permits a long connecting cable between the Head and the Control Unit which contains an output amplifier and stabilized power supply. It also means that the Head's output signal is in a form which is readily acceptable by most recording instrumentation and therefore when operated using batteries the Head may be used as a portable measuring instrument, without the use of the Control Unit. This could be found especially useful when making field measurements.

Features of the 2631 are automatic and manual compensation enabling microphones with different cartridge capacitances to be used, built in time constants which permit lower limiting frequencies of 0.01, 0.1, 1 Hz and DC to be selected and a monitoring meter which provides an indication of the approximate peak level of the output signal from the 2631.

The 2631 may be used with any of the 1 inch and 1/2 inch condenser microphones in the B & K range. However, for sound pressure measurements where an extremely low frequency response is required special

condenser microphones which have a long equalization time constant must be employed. The B & K microphones which have this and are therefore especially recommended for use with the 2631, are the 1 inch Microphone Type 4146 and the 1/2 inch Microphone Type 4147. The 4146 has a frequency response extending from 0.1 Hz to 8 kHz (linear to ±3 dB) whilst the 4147 (which must be used with the special adapter Type UA 0271) has a frequency response extending from 0.01 Hz to 16 kHz (linear to ±1 dB), and will therefore be found useful for sonic bang measurements with the 2631. For DC measurements on static or very slowly varying air or gas pressures the 1/2 inch Microphone Type 4134 may be used, provided it is fitted with the adapter proposed in section 5.2 of this manual.

2. CONTROLS

2.1. MICROPHONE AND MICROPHONE HEAD

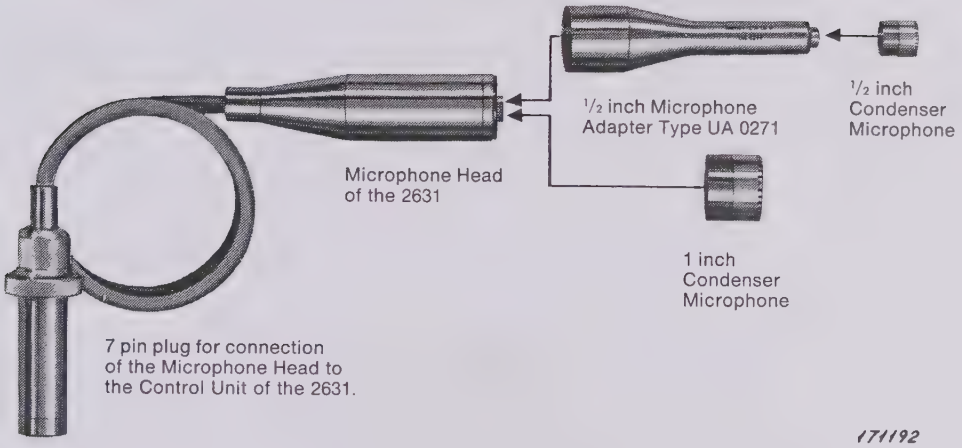


Fig.2.1. Microphone plus Microphone Head

CONDENSER MICROPHONE: A condenser microphone (not provided with the 2631) screws onto the Microphone Head and acts as the transducer for pressure measurements with the 2631. The B & K microphones especially recommended for low frequency measurements with the 2631 are the 1 inch Microphone Type 4146 and the 1/2 inch Microphone Type 4147. The 4147 must be used with the special 1/2 inch Microphone Adapter Type UA 0271. For information on these and other microphones that may be used, section 4.1 of this manual should be consulted.

MICROPHONE HEAD: Contains an FM detector to detect the changes in Microphone output capacitance

due to pressure variations at the microphone's diaphragm. The output for the Head's demodulated output signal as well as the inputs for the Head's supply and control voltages are via a 7-pin microphone plug which is attached to the Head via a 2 metre long cable. The plug connects into the INPUT socket of the Carrier System's Control Unit.

For field measurements the Head may be used as a battery operated measuring instrument, without the use of the Control Unit. See section 3.6.

2.2. CONTROL UNIT

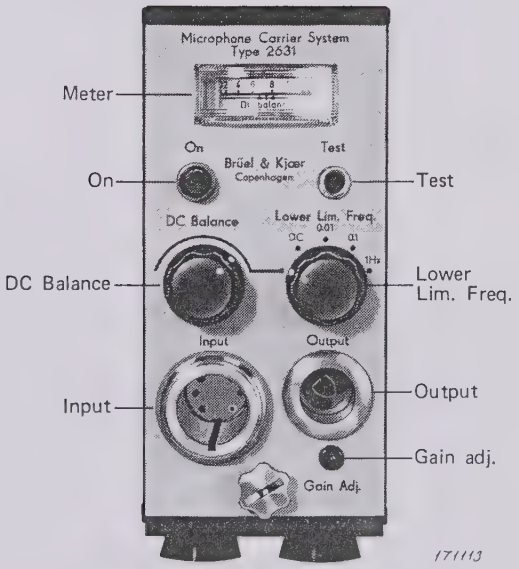


Fig.2.2. Front panel of the Control Unit of the 2631

2.2.1. Front Panel

METER: Indicates the approximate peak level of the output signal voltage from the 2631. It also

provides an indication of the DC balance when the 2631 is calibrated for measurements using its DC mode.

ON: Indicator lamp which lights when the mains supply is connected to the POWER SOCKET on the rear panel of the Control Unit and when the power ON/OFF switch, also on the rear panel, is set to "On".

DC BALANCE: Sets output bias level to zero when measurements are made using the 2631 in its DC mode. To obtain a meter indication of DC balance set the LOWER LIMITING FREQUENCY switch to its extreme anti-clockwise position.

INPUT: 7-pin socket for connection of the Carrier System's Microphone Head. The socket provides an input to the Control Unit for the Microphone Head's demodulated output signal. Outputs are also provided on this socket for the Control Unit to supply the Microphone Head's supply and feedback voltages.

Note: Except for the Microphone Head supplied with the 2631 it is not permissible to connect any other type of microphone head or preamplifier to the INPUT socket of the Control Unit.

GAIN ADJ.: Screwdriver operated potentiometer for adjustment of the gain of the Control Unit's output amplifier.

OUTPUT: Coaxial socket for connection of a 7001 Tape Recorder or a 2305 Level Recorder etc. to the output of the 2631. The socket is also connected in parallel with an OUTPUT socket on the rear panel. The output impedance of the socket is less than 10Ω, but should not be loaded by less than 1 kΩ.

Note: A DC voltage of up to ± 12 V can exist at the OUTPUT sockets if the DC BALANCE control is not correctly adjusted and the LOWER LIMITING FREQUENCY switch is set in its DC mode or extreme anticlockwise position.

LOWER LIMITING FREQ.: Sets the lower limiting frequency of the 2631. When in the 0.001, 0.01 and 1 Hz positions (i.e. AC modes) the response of the 2631 without microphone falls from its linear value by up to 1 dB at the frequency selected. The upper frequency limit is 150 kHz. When in the "DC" position (DC mode) the response of the 2631 is that of the microphone employed. Without microphone the response extends from DC to 150 kHz. A further switch position, is also provided to give a meter indication of the DC balance. This is used when calibrating the 2631 for measurements using the DC mode of the LOWER LIMITING FREQUENCY switch. In the AC modes balance is automatic.

TEST: When this button is pressed, an oscillator injects a 1 kHz test signal into the Microphone Head's resonant circuit. The amplitude of the test signal can be adjusted internally (see section 3.5) and is used to provide a simple check on whether the 2631 is calibrated and functioning correctly.

2.2.2. Rear Panel

ON/OFF: ON/OFF switch for power.

OUTPUT: 10–32 NF socket for connection of a meter etc. to the output of the 2631. The socket is connected in parallel with the OUTPUT socket on the front panel and has an output impedance of less than 10Ω, but should not be loaded by less than 1 kΩ.

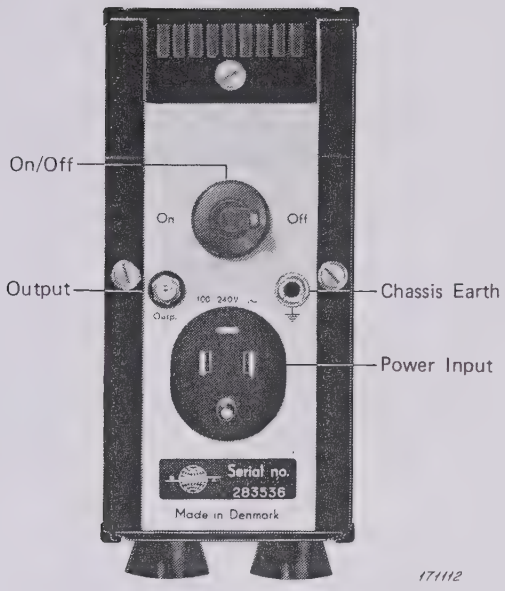


Fig.2.3. Rear panel of the Control Unit of the 2631

Note: A DC voltage of up to ± 12 V can exist at the OUTPUT if the DC BALANCE is not correctly adjusted and the LOWER LIMITING FREQUENCY switch is in its DC mode or extreme anticlockwise position.

CHASSIS EARTH:

Can be used for grounding the chassis of the Control Unit to the earth of the mains supply. It should not be used when the earth of the mains supply is already used to ground one of the shields of the mains transformer. See POWER INPUT.

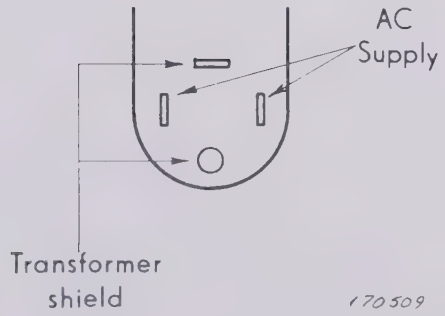


Fig.2.4. POWER INPUT socket of the 2631

POWER INPUT:

For connection of AC mains supply. Any mains voltage between 100 and 240 Volts AC (50 to 400 Hz) is suitable and no adjustment is necessary. Provision is also made on this socket for grounding one of the mains transformer shields to the earth of the mains supply (see Fig.2.4). The AC power fuse is located at the rear of the Control Unit and is accessible by removing the bottom panel of the instrument (see section 3.7). The fuse rating is 50 mA, 250 Volt.

3. OPERATION

3.1. CONNECTION OF 2631 FOR CALIBRATION AND MEASUREMENTS

1. Fit a Condenser Microphone (see section 4.1) to the Microphone Head of the 2631. If a 1/2 inch microphone is used, it should be fitted to the Microphone Head using the Adapter Type UA 0271.

2. Fit the 7-pin plug of the Microphone Head to the INPUT socket of the Control Unit.

3. Connect the POWER socket of the Control Unit to the mains supply. Any mains supply voltage between 100 and 240 Volts AC (50 to 400 Hz) is suitable and no adjustment is necessary.

4. Connect the OUTPUT sockets of the Control Unit to the measuring instrumentation.

3.2. DC BALANCE OF OUTPUT SIGNAL FROM THE 2631

3.2.1. For "DC" LOWER LIM. FREQ. Mode

For measurements using the "DC" LOWER LIM. FREQ. mode of the 2631 it is important to ensure that the DC balance of the output signal is set correctly. To do this proceed as follows:

1. Connect the 2631 as described in section 3.1 and switch the power ON/OFF switch to "On"

2. Set the LOWER LIM. FREQ. switch to its extreme anticlockwise position.

3. Place the microphone plus Microphone Head in a fixed position, in an environment free from any large external pressure influences.

4. Adjust the DC BALANCE control so that the needle of the monitoring meter rests between the two arrows on the meter scale.

3.2.2. For AC LOWER LIM. FREQ. Modes

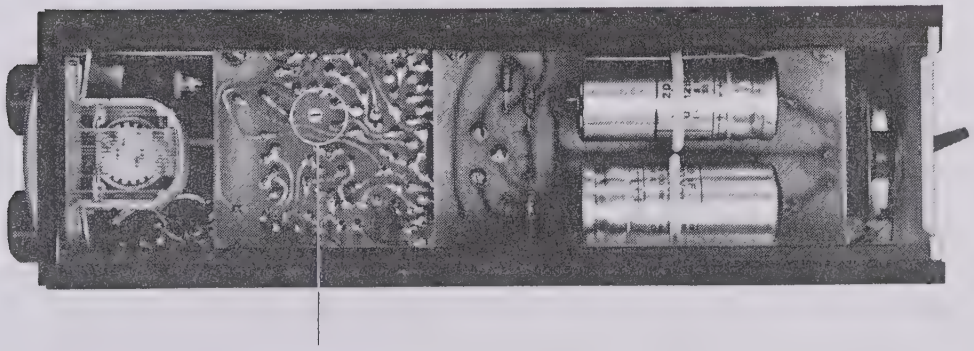
For measurements using the AC LOWER LIM. FREQ. modes (0.01, 0.1 and 1 Hz) of the 2631 the DC balance of the output signal is adjusted automatically to within ±20 mV. However, if it is required that the DC balance of the output signal should be more precise than this, the following adjustment should be made. It should be pointed out that this adjustment need only be made once when the instrument is used for the very first time.

1. Remove the top panel of the Control Unit by unscrewing the top fixing screw on the rear panel and sliding the top panel to the rear of the instrument.

2. Connect a DC valve voltmeter to one of the OUTPUT sockets of the Control Unit.

3. Set up the 2631 as described in section 3.1 and switch the power ON/OFF switch to "On".

4. Set the LOWER LIM. FREQ. switch to its "1 Hz" mode.



DC balance adjustment for AC modes

Top view of module with top panel removed

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Fig.3.1. Adjustment of DC balance for AC LOWER LIM. FREQ. modes

5. Place the microphone plus Microphone Head in a fixed position and in an environment free from any large external pressure influences.

6. Adjust the preset potentiometer shown in Fig.3.1 so that the DC valve voltmeter indicates zero volts on its most sensitive range.

3.3. CALIBRATION

3.3.1. Using the Pistonphone or Sound Level Calibrator

1. Set up the 2631 as described in section 3.1 and 3.2.

2. Set the LOWER LIM. FREQ. switch to the lower limiting frequency required for measurements. If the DC mode of the switch is to be used, set the DC balance of the output signal as described in section 3.2 and then select the "DC" LOWER LIM. FREQ. mode.

3. Using the Pistonphone Type 4220 or the Sound Level Calibrator Type 4230, the recording instrument should indicate 124 or 94 dB respectively. If it does not, adjust the GAIN ADJ. control of the Control Unit and the input attenuator of the recording instrument until the correct indication is obtained.

3.3.2. Using Change in Atmospheric Pressure with Height

If an accurate sound pressure reference source is not available for calibration of the 2631 measurement system, then the change in atmospheric pressure with height may be used. However this type of calibration relies on the fact that a reference pressure must be stored in the microphone's cavity (see Fig.4.2) and therefore it is essential that a microphone which has a long equalization time constant is employed with the 2631. This is because the equalization time constant determines the maximum rate at which the "stored" pressure level can change due to air entering or leaving the cavity via the microphone's static pressure equalization vent. A relationship which relates the equalization time constant of a microphone to the maximum rate at which the pressure level in the microphone's cavity can change is given by:

$$\frac{\Delta p}{\Delta t} = \frac{8 \cdot 6}{\tau} \qquad 3.1.$$

where $\Delta p/\Delta t$ is the rate of change of the pressure level given in dB/sec and τ is the equalization time constant of the microphone in sec. It can be seen therefore that provided the pressure outside the microphone can change more rapidly than the pressure level in the cavity, then a pressure difference will exist across the microphone's diaphragm and this will be detected by the 2631 which will produce a proportionate output voltage. This pressure difference may also be produced by allowing the pressure in the cavity to equalize with the atmospheric pressure outside the microphone and then moving the microphone's position to a level where the atmospheric pressure outside the microphone is different. Consequently for a short period of time (depending on the equalization time constant of the microphone) the pressure difference existing across the microphone's diaphragm will be the same as the difference in atmospheric pressure which is proportional to the height the microphone was moved. An expression which relates the amount by which the atmospheric pressure changes with height is given by:

$$\frac{\Delta p}{\Delta h} = -4.548 \frac{p_o}{T + 273} \qquad 3.2.$$

where $\Delta p/\Delta h$ is the change in atmospheric pressure with height in N/m^2 per m, p_o is the atmospheric pressure in mm Hg at the level from which the microphone is moved and T is the ambient temperature in ^oC.

From equation 3.2 an expression can be derived from which can be calculated the height by which the microphone position can be changed in order to produce a pressure difference which is suitable for calibration purposes:

$$h = P_c \frac{(T + 273)}{4.548\ P_o} \qquad 3.3.$$

where h is the height in m, P_c is the pressure in N/m^2 required for calibration, T is the temperature in ^oC and P_o is the atmospheric pressure in mm Hg at the level from which the microphone is to be moved.

Using equation 3.3 the 2631 may be calibrated for pressure measurements as follows.

1. Set the DC balance of the 2631 as described in section 3.2.

2. Having obtained balance, set the LOWER LIM. FREQ. switch to its "DC" mode. The position of the microphone should not be changed.

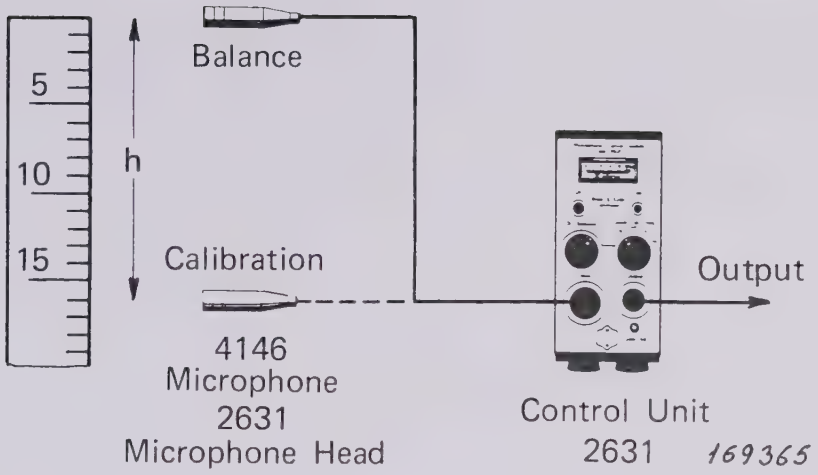

Fig.3.2. Instrument set up for coarse calibration of the 2631

3. Using equation 3.3 calculate the height by which the microphone must be moved in order to produce a sound pressure level which is suitable for calibration.

   Example.
   If the atmospheric pressure at the microphone position used for balance is 760 mm Hg and the temperature is $0^{o}C$ then the height by which the microphone's position must be changed in order to produce a pressure of 20 N/m^2 (i.e. 120 dB re 2 x 10^{-5} N/m^2) for calibration, is given by:

$$h = 20 \frac{(0 + 273)}{4.538 \times 760}$$

$$h = 1.58 \text{ m}$$

4. Displace the microphone by the height calculated in item 3 to a point immediately below the position used for balancing the system.

5. Using the GAIN ADJ. control on the Control Unit or the input attenuator of the recording or measurement instrument, adjust the sensitivity of the system so that the recording or measuring instrument indicates the calibration pressure P_c. This adjustment should be made as quickly as possible, since after the microphone's position is changed the pressure used for calibration will decay at a rate which can be determined from equation 3.1.

3.4. EVALUATION OF THE OUTPUT VOLTAGE AVAILABLE FROM THE 2631

When a recording or measuring instrument is to be connected to the OUTPUT of the 2631 it may sometimes be useful to be able to determine the output voltage available from the 2631 when it is used with a microphone and a known sound pressure is applied. This will also be found useful for when checking the function of the 2631.

A formula which enables the output voltage from the 2631 to be calculated when the 2631 is used with a 1 inch or 1/2 inch microphone is given by:

$$E_{out} = P \cdot K \cdot S_M \cdot S_s \qquad 3.4.$$

where E_{out} is the output from the 2631 in Volts

P is the applied pressure in N/m^2

K is a conversion factor by which the sensitivity of a microphone is increased when an adapter is used. For 1/2 inch microphones when Adapter UA 0271 is used, $K = 3$. For 1 inch microphones an adapter is not required and therefore $K = 1$.

S_M is the sensitivity of the microphone employed in pF per N/m^2

S_s is the sensitivity of the 2631 which ranges from approximately 1.2 Volts/pF when the GAIN ADJ. control is in its extreme anticlockwise position, and 6 Volts/pF when the GAIN ADJ. control is in its extreme clockwise position.

Example:

When the 2631 is used with a 1 inch microphone of sensitivity $12.5\ 10^{-3}$ pF per N/m^2 and a sound pressure level of $2N/m^2$ is applied, the output voltage available from the 2631 when its sensitivity is set to 6 Volts/pF may

be calculated as follows:

from equation 3.4

$$E_{out} = P \cdot K \cdot S_M \cdot S_s$$
$$= 2 \times 1 \times 12.5\ 10^{-3}\ 6$$
$$E_{out} = 150\ mV$$

3.5. USE OF TEST OSCILLATOR

Once calibration has been obtained for a microphone, the inconvenience of recalibrating that particular microphone can be avoided by using the test oscillator. The amplitude of the oscillator should be adjusted to provide some convenient indication on the measuring and recording instrumentation (up to 145 dB indication available with the 1 inch Condenser Microphone fitted). For later calibrations the GAIN ADJ. is used to adjust the Test signal to its reference level. The accuracy of the test oscillator is ± 0.3 dB for temperature variations less than $\pm 5^{o}C$.

The amplitude of the test oscillator may be adjusted using the internal multi-turn preset potentiometer shown in Fig.3.3. The potentiometer is

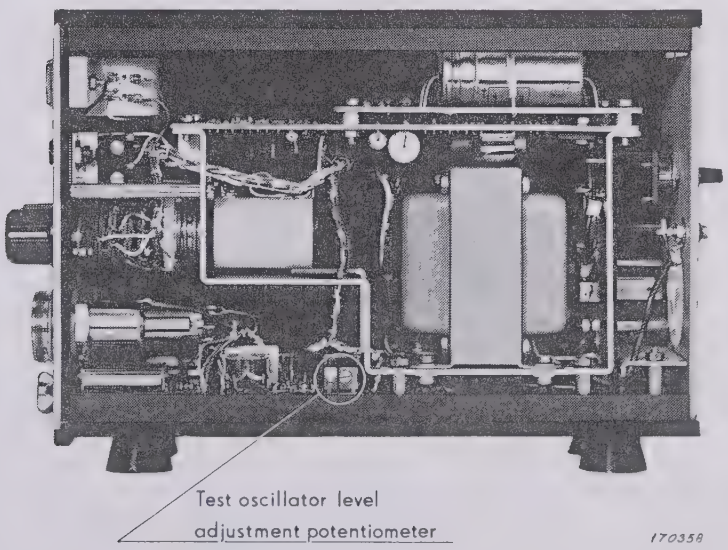

Fig.3.3. Adjustment of test Oscillator level

accessible by removing the Control Unit's left side panel (as viewed from rear panel of instrument) as described in section 3.7.

3.6. BATTERY OPERATION

The Microphone Head of the 2631 is unlike the heads of most conventional types of microphone carrier systems in that it produces a demodulated output signal which is suitable for recording purposes. This has a number of important advantages, one of which is that when the Control Unit of the 2631 is replaced by the circuit shown in Fig.3.4, the Microphone Head may be used as a portable measuring instrument.

The circuit (Fig.3.4) is connected to the 7-pin plug of the Microphone Head and provides the supply voltages necessary to operate the Head's circuitry from two 12–15 volt batteries. The 5–10 kΩ potentiometer shown is used to set the DC balance of the Head's output signal which is taken from pin 4 and 7 of the plug. The output impedance of the Head is less than 100 Ω and is suitable for connection to most recording or measuring instrumentation. It should not, however, be loaded by less than 1 kΩ. The approximate sensitivity of the Head and its maximum output voltage are 1.2 Volts/pF and 10 Volts peak respectively.

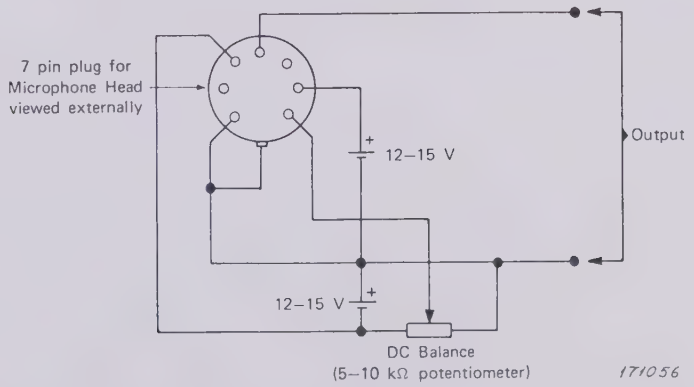

Fig.3.4. Circuit for battery operation of Microphone Head

3.7. REMOVAL OF CONTROL UNIT PANELS

The BOTTOM PANEL of the 2631 Control Unit is removed by releasing the large finger screw at the bottom of the front panel (see Fig.2.2). Quarter

to half a turn should be adequate to release the catch. The panel is then removed by sliding it towards the rear of the unit.

TOP and SIDE PANELS of the instrument can each be released by unscrewing the fixing screws on the rear of the unit (see Fig.2.3). These panels are also removed by sliding them backwards.

4. DESCRIPTION

A schematic diagram of the 2631 Microphone Carrier System is shown in Fig.4.1. A detailed description of the system's design and its operation with a condenser microphone follows:

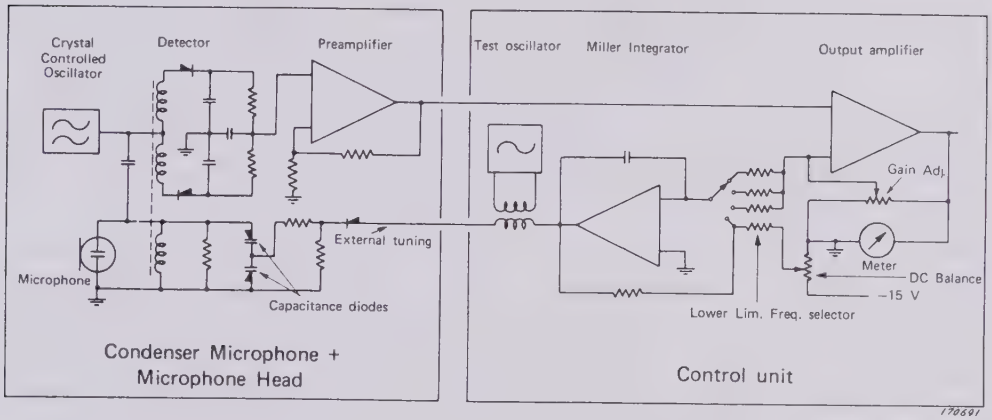

Fig.4.1. Schematic diagram of the 2631

4.1. CONDENSER MICROPHONE

A condenser microphone (not provided) acts as the transducer for sound and pressure measurements with the 2631. However, in order to realize a very low frequency measurement capability special types of condenser microphone must be employed in which the microphone's pressure equalization vent has been designed to give a long equalization time constant. For this reason only the B & K 1 inch Condenser Microphone Type 4146 and the 1/2 inch Condenser Microphone Type 4147 are recommended, since both types have long equalization time constants.

With the 4146, the equalization time constant is greater than 1.6 sec. and is obtained by partially sealing the equalization vent with a silicon rubber ring (see Fig.4.2). This gives the 4146 a frequency response which is linear from 8 kHz down to 0.1 Hz (± 3 dB).

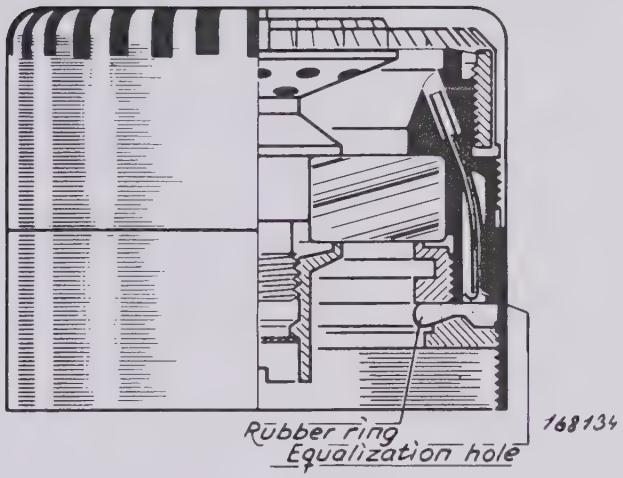

Fig.4.2. 1 inch Condenser Microphone Type 4146

With the 4147 sealing has not been necessary as its vent has been designed to produce an equalization time constant which is greater than 31.8 sec. This gives the 4147 a response which is linear from 16 kHz down to below 0.01 Hz (± 1 dB). However, when employing the 4147 with the 2631, an Adapter Type UA 0271 should be fitted. The Adapter is shown in Fig.4.3. It matches the output capacitance of the microphone into the Microphone Head, whilst at the same time effectively increasing the sensitivity of the microphone.

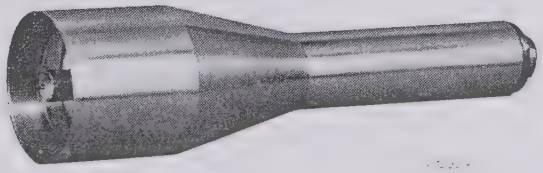

Fig.4.3. The special 1/2 inch Microphone Adapter Type UA 0271

Using the Sealing Kit Type UA 0240 the low frequency response of 1 inch Microphone Types 4144 and 4145 may also be extended. However,

the response of these microphones when sealed cannot be guaranteed. For a low frequency response of 0.01 Hz and below, section 5.1.4 of this manual should be consulted.

4.2. MICROPHONE HEAD

When a condenser microphone is screwed onto the Microphone Head the microphone output capacitance is coupled into the Head's resonant circuit (see Fig.4.4). The resonant circuit forms the tuned input stage of an FM discriminator and is coupled to a 10.245 MHz crystal controlled oscillator. Any change in the microphone's output capacitance due to sound pressure variations at its diaphragm causes the impedance of the resonant circuit to change, causing frequency modulation. The resonant circuit is inductively coupled to the detection circuit of the discriminator, which demodulates the frequency modulated signal by detecting the impedance change of the resonant circuit. The phasing of the system is such that the discriminator's demodulated output signal is directly proportional to the sound pressure at the microphone's diaphragm. An integrated circuit preamplifier amplifies the demodulated signal from the discriminator by 20 dB and passes it to an output plug. The plug is connected to the Head via a 2 metre long cable and is used to connect the output of the Head's preamplifier to the INPUT of the Control Unit.

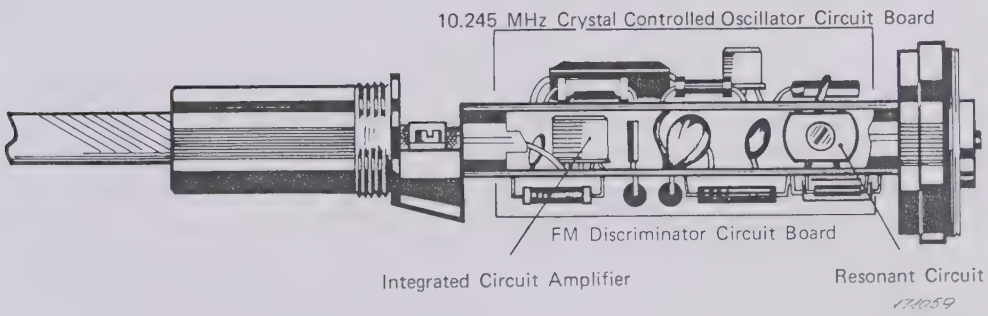

Fig.4.4. Sectional view of Microphone Head with its outer shield removed

The fact that the output from the Head of the 2631 is a demodulated signal and not a frequency modulated one as is common with most conventional types of microphone carrier systems has a number of distinct

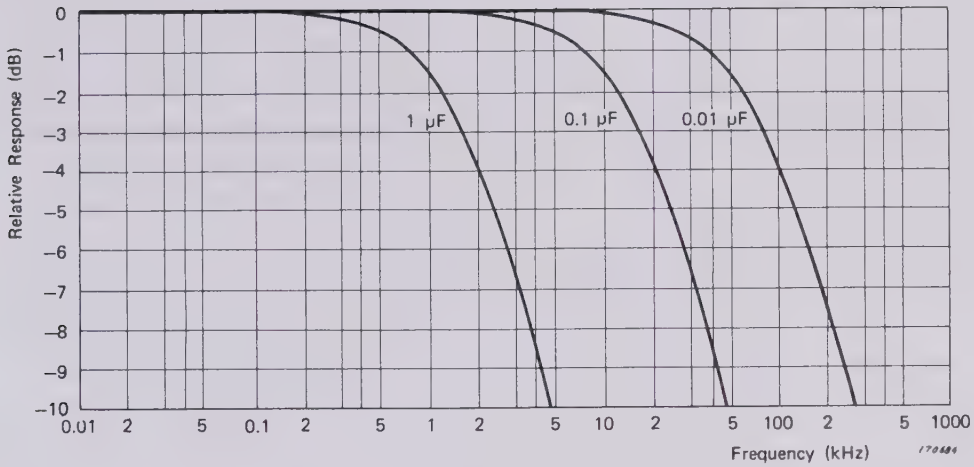

Fig.4.5. Frequency response of the 2631 for capacitive loading of either the Control Unit's OUTPUT sockets or the Microphone Head's output

advantages. The first of these is that because the frequency content of the demodulated signal from the Head is low (DC to 150 kHz) and the output impedance of the Head is less than 100 Ω, the effect of cable capacitance on the response of the system is small (see Fig.4.5 for effect of capacitive loading on the response of the 2631). Thus, without unduly affecting the upper limiting frequency response of the 2631, the 2 metre long cable connecting the output from the Head to the Control Unit may be extended by 10 metres using the B & K Extension Cable Type AO 0028.

The second advantage is that, because the output from the Head is in a form that a recording or measuring device can readily accept, it may be used for measurements down to DC without the use of the Control Unit. This means that the Head of the 2631 can be operated as a portable measuring instrument (see section 3.6) and will therefore be found especially useful for field measurements.

To enable different microphone cartridges to be used with the system by compensating for the effects of different cartridge capacitances, feedback is applied from the Control Unit to two variable capacitance diodes in the Head's resonant circuit. This ensures that the resonant circuit is tuned for microphone cartridge capacitances between 40 and 70 pF and is adequate for any of the B & K 1 inch Microphones. For 1/2 inch Microphones however, a special Adapter Type UA 0271 is required.

4.3. CONTROL UNIT

The input to the Control Unit for the demodulated output signal from the Microphone Head is via a standard B & K 7-pin microphone socket. The socket is directly coupled to one of the inputs of the Carrier System's differential output amplifier which has an input impedance of approximately 15 kΩ. The gain of the amplifier is adjustable from 0 dB to 14 dB and is determined by the setting of the GAIN ADJ. Potentiometer which controls the amount of voltage feedback applied from the output to the secondary input of the amplifier.

The output of the amplifier is DC coupled to a standard B & K coaxial OUTPUT socket on the front panel of the Control Unit and to a 10–32 NF coaxial OUTPUT socket on the rear panel. The output impedance of the amplifier is less than 10 Ω and is suitable for connection to most types of recording and measuring instrumentation. The minimum DC load that may be connected to the OUTPUT sockets is 1 kΩ. The response of the Carrier System for capacitive loading of the OUTPUT sockets is shown in Fig.4.5.

An output is also taken from the amplifier to provide feedback to two variable capacitance diodes in the Head's resonant circuit. This ensures that the resonant circuit is tuned for microphone cartridge capacitances between 40 and 70 pF and thus provides compensation enabling different condenser microphone cartridges to be used with the Carrier System. The frequency below which compensation for the cartridge capacitance is effective is the Carrier System's lower limiting frequency, which is determined by the integration time of a Miller Integrator in the feedback loop. The integration time of the Miller Integrator may be altered using the Control Unit's LOWER LIM. FREQ. switch, which enables lower limiting frequencies of 0.01, 0.1 and 1 Hz, and DC to be selected. In the AC mode positions (0.01, 0.1 and 1 Hz), compensation is applied automatically whilst in the DC mode compensation is set manually using the DC BALANCE control. DC balance is clearly indicated on a monitoring meter when the LOWER LIM. FREQ. switch is set in its extreme anticlockwise position.

In order to provide a simple check on the function of the Carrier System, the Control Unit is provided with a test oscillator which is inductively coupled into the feedback loop immediately after the Miller Integrator. By pressing the TEST push button on the front panel of the Control Unit the test oscillator may be used to inject a 1 kHz signal into the Head's resonant circuit. The injected signal "pulls" the capacitance diodes in the resonant circuit causing a capacitance variation which is detected and displayed on the Control Unit's monitoring meter. The amplitude of the oscillator output

signal may be adjusted using an internal preset potentiometer (see section 3.5).

Also contained in the Control Unit is a stabilized power supply which provides + 15 and −15 Volts for circuitry contained in both the Microphone Head and the Control Unit. The stabilized supply is mains driven and suitable for operation with any 50 to 400 Hz mains supply voltage between 100 to 240 Volts. The current consumption is 20 mA.

4.4. FREQUENCY CHARACTERISTICS OF THE 2631

The frequency response of the 2631 (without microphone) is from 150 kHz down to a lower limiting frequency which is determined by the setting of the Control Unit's LOWER LIM. FREQ. switch. It should be noted that unlike the cut-off frequency (−3 dB point), the lower limiting frequency is an arbitrary limit placed on a system to indicate its low frequency response and may be defined as required. In the case of the 2631 in its AC mode the low frequency response of the Carrier System (see Fig. 4.6) falls by up to 1 dB at the LOWER LIMITING FREQUENCY selected. If a microphone is employed which has the same lower limiting frequency response as that selected on the 2631, then the response of the system will fall by up to 2 dB at the frequency selected. In the DC mode the low frequency response of the 2631 is that of the microphone employed. Without microphone the response of the 2631 in this mode is flat down to DC.

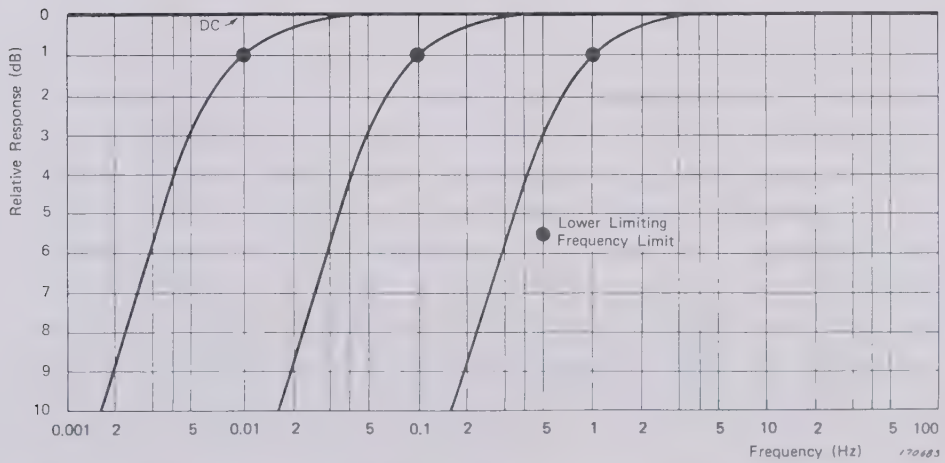

Fig.4.6. Lower limiting frequency response of the 2631 (without microphone) for both the AC and DC modes of the LOWER LIM. FREQ. switch

5. APPLICATIONS

The applications of the B & K Carrier Microphone System Type 2631 are numerous and cover almost any field where measurements of slowly varying air pressures and short duration pulses are sought. Discussion here is confined to the sonic bang and pressure measurements.

5.1. SONIC BANG MEASUREMENTS

5.1.1. General

The very low frequency response of the 2631 and its wide dynamic range make it especially useful for the measurement of sonic bangs.

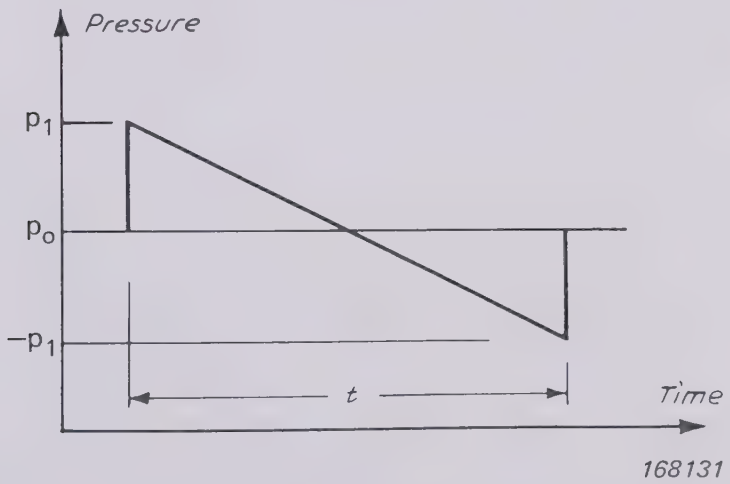

Fig.5.1. Idealized N wave of sonic bang

Taking for example the idealised N wave of a sonic bang from an aircraft (Fig.5.1), the peak overpressure, p_1 may be 250 N/m^2 (5 lb/ft^2) or possibly even higher for low flying aircarft, and the pulse duration, t, of the order 0.03 to 0.4 sec. A Fourier integral of such an N wave shows that its spectral content (Fig.5.2) peaks at about 1/t Hz and ranges several decades above

and below this frequency. For accurate representation of such spectra it is necessary to have measurement capability from 0.01 Hz to 10 kHz as recommended by the ISO draft proposal for sonic bang measurements. The suggestions contained in this section comply to this proposal which should be consulted for further detail.

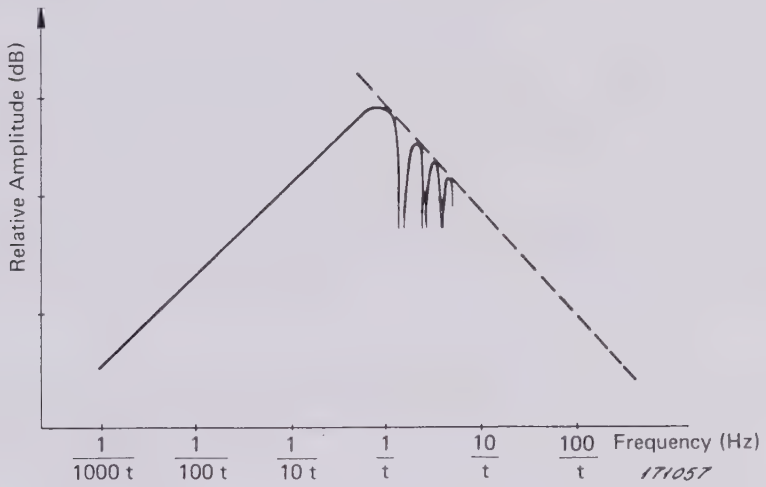

Fig.5.2. Fourier spectrum of sonic bang

5.1.2. Measuring Environment

When sonic bang measurements are to be taken from ground level, an open space reasonably free from obstructions and local undulations is required, with a hard surface in the form of a securely mounted, rigid baffle (1.5 m diameter, or more) surrounding the measurement point. If obstructions are present then they should not subtend a solid angle greater than 0.004 steradians.

Free air conditions apply when the microphone can be mounted at sufficient height and when obstructions in the upper half space do not subtend an angle greater than 0.004 steradians. This may necessitate an altitude of more than 100 m for the whole sonic bang pressure signature to be determined. However, a lower height may be found sufficient to resolve the rise terms.

Any deviations from the conditions specified above should be stated with the measurements obtained.

5.1.3. Microphone and Installation

For sonic bang measurement when the upper limiting frequency is 10 kHz or greater, a B & K 1/2 inch Condenser Microphone Type 4147 with Head Adapter Type UA 0271 is recommended. This is to avoid measurement errors due to the transit time of the shock across the microphone diaphragm.

For installation of the microphone at ground level, its diaphragm should be mounted facing directly upwards and flush with the surrounding baffle and ground. However, where this is impracticable the microphone can be mounted in either a vertical or horizontal position with its diaphragm as close to the gound as possible, but avoiding a face down condition. The microphone body and all measuring equipment should be below ground or sufficiently remote that their proximity does not influence the measurements.

Extraneous signals due to ground vibration and wind etc., can be avoided by providing the microphone with a shock-isolated mounting and a Wind Screen Type UA 0082.

5.1.4. Extension of Microphone Lower Limiting Frequency

If only a conventional type of condenser microphone is available for measurements with the 2631, then the microphone's lower limiting frequency response may be extended. However, to do this it is first necessary to consider the factors influencing the movement of the microphone's diaphragm at low frequencies. For the diaphragm to move, a difference must exist between the pressure outside the microphone and the pressure in the cavity behind the diaphragm. The diaphragm will not move when pressure changes take place so slowly that air enters the cavity via the equalization vent allowing the cavity's pressure to increase at the same rate as the outside pressure. The rate at which the pressure in the cavity can increase due to air entering the cavity via the vent is determined by the volume of the cavity and the size of the vent. These form the equivalent of an electrical time constant in which the size of the vent and the volume of the cavity are proportional to the respective RC components. It is this time constant which determines the lower limiting frequency.

A method of extending the lower limiting frequency by effectively increasing the volume of a microphone's cavity is shown in Fig.5.3. Here the microphone's protection grid is removed and the microphone's diaphragm

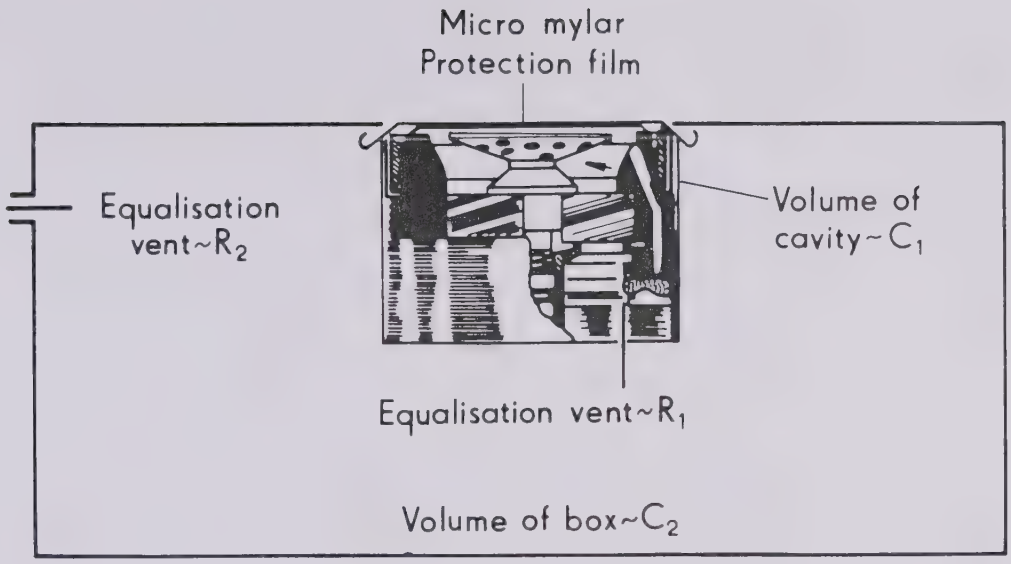

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Fig.5.3. Method by which the lower limiting frequency response of a microphone may be extended by mounting the microphone in a box which has an equalization vent

covered with a micro-mylar protection film. The microphone is then mounted in a box with its diaphragm flush with one of the outside faces of the box. The volume of the box is equivalent to a capacitance which is given by:

$$C_2 = V \cdot 10^{-5}$$

where C_2 is the capacitance (m^5/N) and V is the box's internal volume (m^3).

A capillary tube mounted in one side of the box acts as an equalization vent. The size of the vent is equivalent to a resistance which is given by:

$$R_2 = \frac{L}{r^4} 4.736 \ 10^4$$

where R_2 is the resistance (Ns/m^5), L is the length of the vent (mm) and r is the vent's internal radius (mm).

The time constant formed by C_2 and R_2 represents the time constant of the box τ which is given by

$$\tau = C_2 R_2 \quad \text{sec.} \qquad 5.3.$$

Fig.5.4 shows the equivalent electrical circuit of the microphone mounting in Fig.5.3. The equivalent circuit components are related by the two figures with the exception of C which represents the compliance of the microphone's diaphragm.

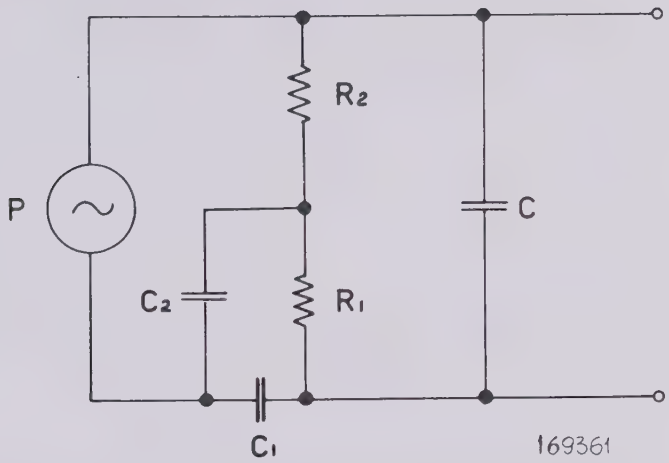

Fig.5.4. Equivalent circuit of microphone mounting shown in Fig.5.3.

Provided the time constant of the box is designed to be much larger than that of the microphone, then the effect of the microphone's time constant can be ignored. Consequently the microphone when mounted in a box will have a lower limiting frequency which is given by:

$$f = \frac{1}{2 \pi \tau}$$

where f is the lower limiting frequency (Hz).

Example:

For a box of volume 10^{-3} m^3 with an equalization vent which is 100 mm long and has an internal radius of 0.15 mm the lower limiting frequency can be calculated as follows:

$$C_2 = V \cdot 10^{-5} \qquad 5.1.$$

$$= 10^{-3}\ 10^{-5}$$

$$C_2 = 10^{-8}\ m^5/N$$

and $$R_2 = \frac{L}{r^4} 4.736\ 10^4 \qquad 5.2.$$

$$= \frac{100}{(0.15)^4} 4.736\ 10^4$$

$$R_2 = 9.358\ 10^9\ Ns/m^5$$

Therefore

$$\tau = C_2\ R_2 \qquad 5.3.$$

$$= 10^{-8}\ 9.358\ 10^9$$

$$\tau = 93.58\ sec.$$

Consequently when this mounting is used with a microphone the microphone's lower limiting frequency response will be extended down to

$$f = \frac{1}{2\ \pi\ \tau}$$

$$f = \frac{1}{2\ \pi\ 93.58}$$

$$f = 0.0017\ Hz$$

Experimental results using a 1 inch Condenser Microphone Type 4145 with the mounting given in the example extended the microphone's lower limiting frequency response down to 0.002 Hz, which shows reasonable agreement to the value calculated in the example. Without this mounting the microphone had a low frequency cut-off of 2 Hz.

It should be pointed out that this method of extending a microphone's lower limiting frequency response also results in an increase of about 2 dB in the microphone's sensitivity. This occurs in the extended region of the microphone's frequency characteristics and is due to a decrease in air stiffness within the microphone's cavity.

5.1.5. Measurement and Analysis

A typical sonic bang measurement set up using the 2631 Carrier System with a 1/2 inch Microphone is shown in Fig.5.5. For recordings of the complete pressure signature the B & K Tape Recorder Type 7001 is

recommended as its response ranges from DC to 20 kHz, when a tape speed of 60 in/sec. is employed. The dynamic range of the recorder is 48 dB, but if a greater range is required both recording channels should be utilized, one recording directly from the 2631, the other via a 100 Hz cut off high pass filter, using a different INPUT ATTENUATOR setting. This proposed system (shown dotted in Fig.5.5), not only gives an effective increase in dynamic range but also increases signal to noise. During frequency analysis a network with an inverse characteristic is applied between the output of the tape recorder and the input of the frequency analyzer.

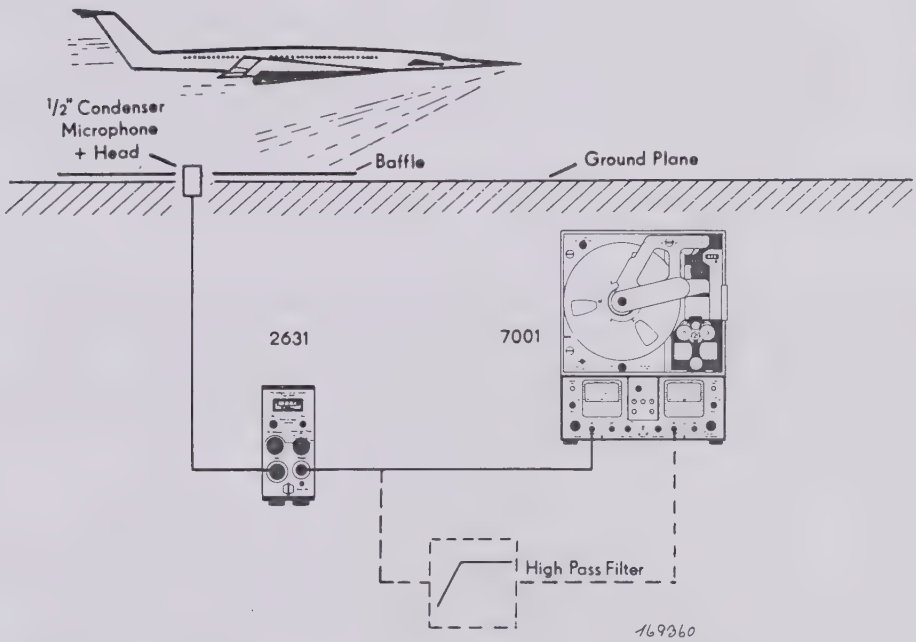

Fig.5.5. Measurement arrangement for sonic bangs

Although the 2631 and 7001 are provided with peak overload meters, accurate pre-determination of the sonic bang pressure level is not possible. Therefore, it is advised that both recording channels (or possibly a number of tape recorders) are used, but with different gain settings. This ensures adequate signal to noise and that one channel utilizes the full dynamic range.

Frequency analysis of the sonic bang pressure signature can be given in the form of either a frequency band spectrum or by a spectral density function. A convenient spectral density function related to the energy

spectral density by a constant factor having the dimensions of acoustic impedance is given by:

$$E = 10 \log_{10} 2\pi \frac{|S(\omega)|^2}{p_o^2 t_o^2} \quad dB$$

where $S(\omega) = \int_{-\infty}^{\infty} p(t)\, e^{-j\omega t}\, dt$

and $p_o = 20\ 10^{-5}\ N/m^2$

$t_o = 1\ s$

$p(t)$ is the overpressure as function of time t, and $p(t) = 2\pi f$.

The level of the band spectrum in the frequency range f_1 to f_2 is then given by:

$$L = 10 \log_{10} \int_{\omega_1}^{\omega_2} \frac{|S(\omega)|^2}{p_o^2 t_o} d\omega \quad dB$$

A band spectrum of the pressure signature frequency components, in the range 20 to 5000 Hz can be obtained graphically on calibrated paper using the 2305 Level Recorder. Analyzing set ups are shown in Fig.5.6 and 5.7. Each requires a tape loop of the pressure signature which on playback can be filtered, either by the 1614/15 Filter Set (1/3 and 1/1 Oct. bandwidths),

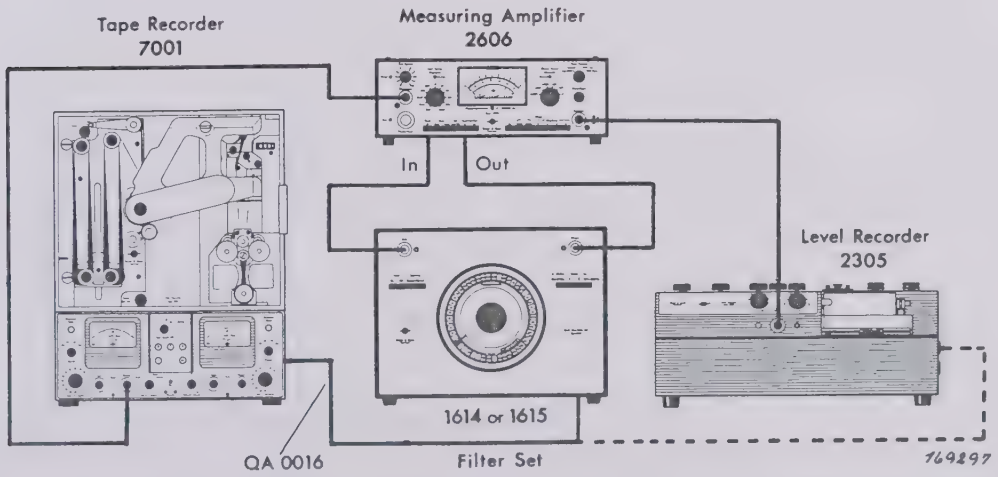

Fig.5.6. Analyzing arrangement using the 1614 or 1615 Filter Sets

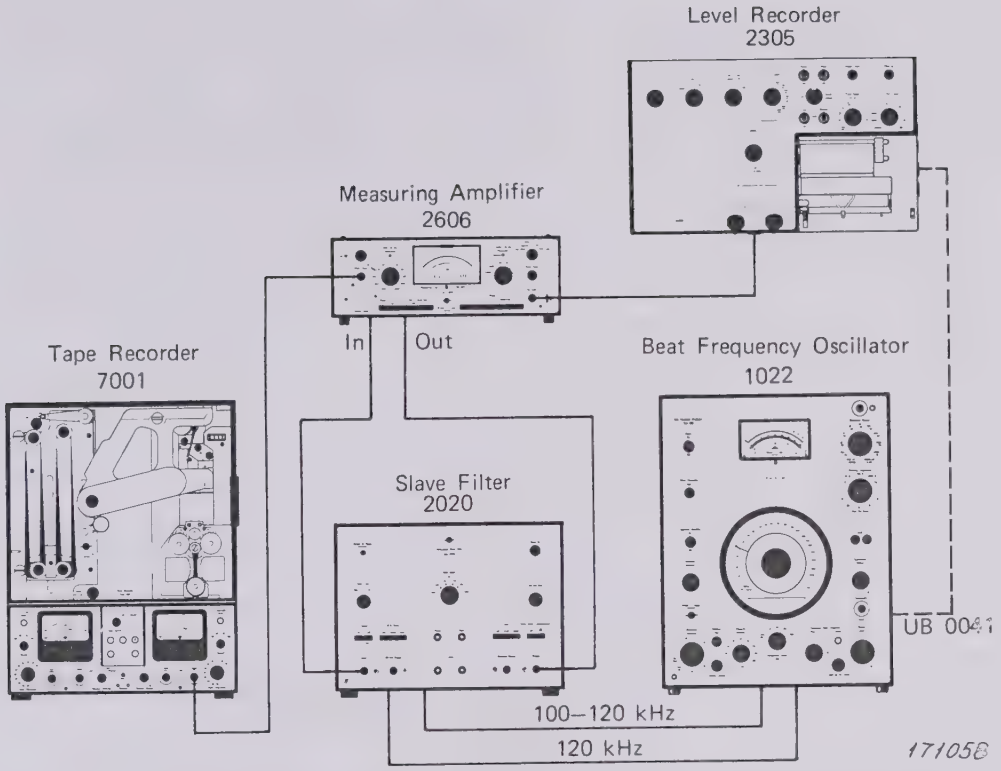

Fig.5.7. Analyzing arrangement using the 2020 Heterodyne Slave Filter

or the 2020 a narrow band Slave Filter (3.16, 10, 31.6 and 100 Hz bandwidths). Both instruments can be automatically scanned, but only the 2020 has the $1/\sqrt{B}$ output attenuator useful in spectral density measurements.

For 0.01 to 20 Hz frequency components, analysis is preformed as before, but because of the lower limiting frequencies of the level recorder and filters, a frequency transformation is necessary and for this two tape recorders are required. One to play back the original pressure signature, but at a speed greater than when originally recorded. The other to re-record it and play it back at a faster speed, thus bringing it into the frequency range required for analysis.

5.2. PRESSURE MEASUREMENTS

For measurement of slowly varying air or gas pressures and where the use of an ordinary manometer is limited as in the measurement of short duration pressure pulses, the 2631 Microphone Carrier System will be found of use.

A proposed microphone adapter for pressure measurements which can be fitted to the B & K 1/2 inch Microphone Type 4134 when used with the 1/2 inch Microphone Adapter Type UA 0271 is shown in Fig.5.8. Except for the two pressure intake nozzles the adapter should form an airtight seal around the microphone. The pressure to be measured should be applied to the microphone diaphragm and the reference pressure to the equalization hole via the appropriate intake nozzle. For the 4134 Microphone the maximum measured pressure difference should not exceed 204 mm of water as the 2631's output would cease to be linear and also damage to the microphone diaphragm may result. A pressure difference of 204 mm of water represents an equivalent sound pressure level of 160 dB.

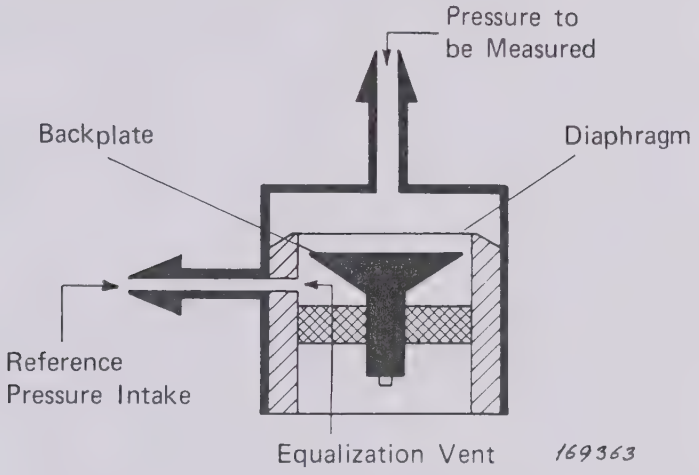

Fig.5.8. Schematic of microphone pressure adapter

Experimental results obtained in the calibration of a 1/4 inch Microphone Type 4136 adapted for pressure measurements (Fig.5.9) show that a reasonably linear output can be obtained from the 2631 in the DC mode. A Betz Manometer was used to determine the precise pressure difference, whilst the output from the 2631 was monitored on an external voltmeter.

Typical areas of research where the 2631 may be used with advantage are in fluid mechanics, pressure chambers and wind tunnels. In the latter case, pressure measurements may be made on moving airfoils (Fig.5.10) or on the transient response of pressure fronts along wind tunnels. In all these applications the 2305 Level Recorder will prove useful in providing a graphical display of pressure behaviour with respect to time.

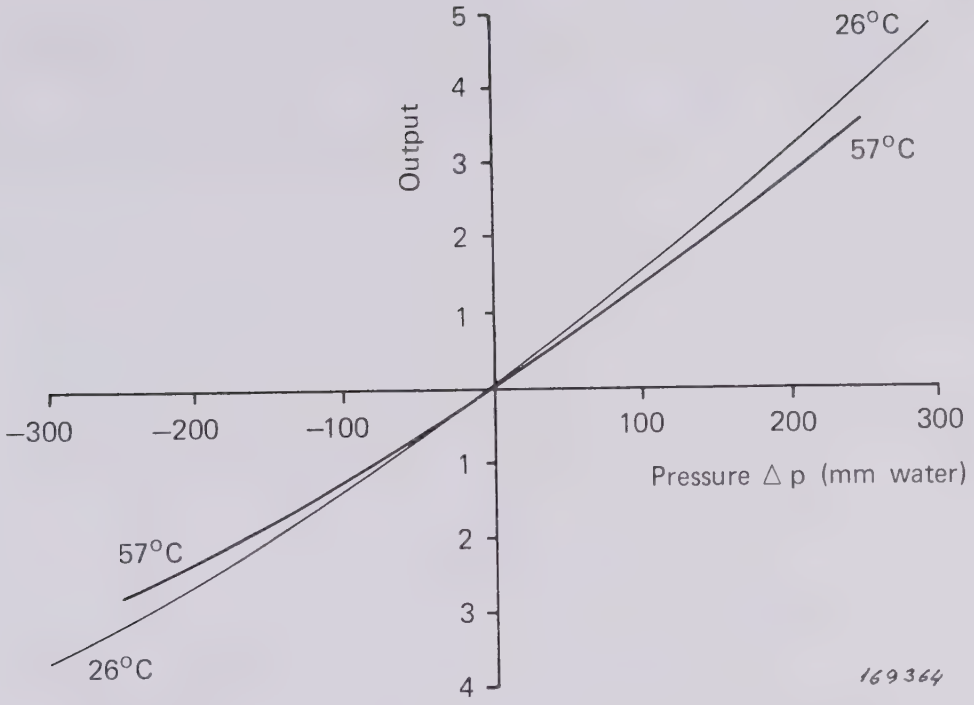

Fig.5.9. Experimental results for calibration of the 1/4 inch Microphone Type 4136 adapted for pressure measurements

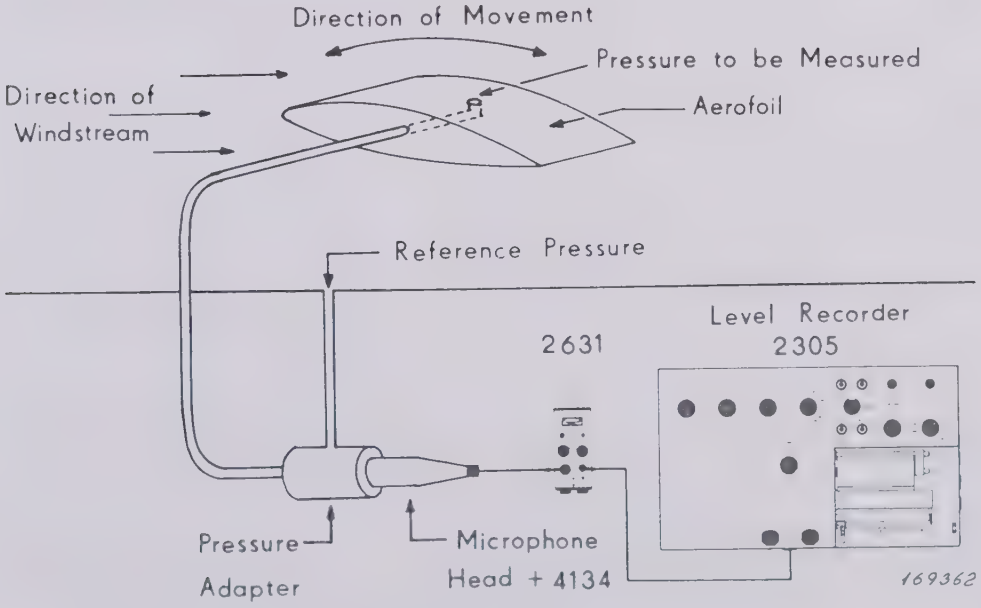

Fig.5.10. Measurements in wind tunnels

Distortion: $<4\%$ at full load

6. SPECIFICATIONS

6.1. CARRIER SYSTEM WITH 1 INCH MICROPHONE TYPE 4146

Upper frequency limit (–3 dB) 8 kHz

Lower frequency limit (–3 dB) <0.1 Hz with "0.01 Hz" or "DC" LOWER LIM. FREQ. modes of 2631

Linear range:
138 dB with 3% distortion
150 dB with 10% distortion

Noise:

0.01 Hz–200 kHz:	0.6 N/m^2
2 Hz–200 kHz:	3.2 10^{-2} N/m^2
2 Hz–20 kHz:	2.5 10^{-2} N/m^2
Curve C:	1.6 10^{-2} N/m^2
Curve A:	1.0 10^{-2} N

Stability in DC mode:
4 N/m^2 per day
0.15 N/m^2 per ^oC

Sensitivity of 4146: approx. 12.5 10^{-3} pF per N/m^2

Sensitivity of 2631 + 4146: 12–60 mV per N/m^2

6.2. CARRIER SYSTEM WITH 1/2 INCH MICROPHONE TYPE 4147 PLUS ADAPTER TYPE UA 0271

Upper frequency limit (–1 dB): 16 kHz

Lower frequency limit (–1 dB): 0.01 Hz with "DC" LOWER LIM. FREQ. mode of 2631

Linear range:
150 dB with 3% distortion
162 dB with 10% distortion

Noise:

0.01 Hz–200 kHz:	2 N/m^2
2 Hz–200 kHz:	0.1 N/m^2
2 Hz–20 kHz:	8.0 10^{-2} N/m^2
Curve C:	5.0 10^{-2} N/m^2
Curve A:	3.1 10^{-2} N/m^2

Stability in DC mode: 13 N/m^2 per day
0.43 N/m^2 per ^{o}C

Sensitivity of 4147: approx. 1.1 10^{-3} pF per N/m^2

Sensitivity of 2631 + UA 0271 + 4147: 3.7–18 mV per N/m^2

6.3. CARRIER SYSTEM ALONE

Upper frequency limit (–3 dB): 150 kHz

Lower limiting frequency (–1 dB): DC – 0.01 – 0.1 – 1 Hz for 2631 serial numbers 283548 and onwards.

Dynamic Range: ±6 pF

Noise:

0.01 Hz–200 kHz:	6 x 10^{-3} pF
2 Hz–200 kHz:	0.3 x 10^{-3} pF
2 Hz–20 kHz:	0.25 x 10^{-3} pF
Curve C:	0.15 x 10^{-3} pF
Curve A:	0.1 x 10^{-3} pF

Stability in DC mode: 0.04 pF/day
0.0015 pF/^{o}C

Sensitivity: 1.2–6 V/pF

Compensation of cartridge capacitance: Automatic at 0.01–0.1–1 Hz.
Manual at DC

Input Capacitance Range: 40–70 pF

Carrier frequency:	10.245 MHz
Max. output of Head:	± 10 V, ± 10 mA
Max. output of Control Unit:	± 10 V, ± 10 mA
Output impedance:	<10 Ω
Min. load impedance:	1 kΩ
Operating temperature:	−20°C to + 60°C
Storage temperature:	−30°C to + 80°C
Meter display:	max. peak, DC or DC balance
Power supply:	100–240 V AC, 50–400 Hz
Power consumption:	approximately 20 mA RMS
Output connectors:	B & K 14 mm socket and 10–32 NF microsocket
Built-in test oscillator:	1 kHz

Above specifications apply at 25°C

Dimensions of Control Unit (KK 0002) excl. knobs and feet:	Height: 132.6 mm (5.22 in) Width: 61 mm (2.40 in) Depth: 200 mm (7.87 in)
Weight of box:	1.65 kg (3.631 lb)
Dimensions of Microphone Head:	Diameter: 23.8 mm (0.94 in) Length: 95 mm (3.75 in) Cable length: 2 m (6.5 ft)
Weight of microphone head:	0.31 kg (0.68 lb)